خودها منه قصيرها

$$\lambda_i = 2\times10^{-7}\left[L_i \ln\left[\frac{1}{r'}\right] + \sum_{j=1}^{n} L_j \ln\left[\frac{1}{D_{ij}}\right]\right]$$

$a^2+a+1=0 \quad I_B = a^2 I_a \quad I_C = I_a a$

$a^2 = \angle 240 \quad a = \angle 120$

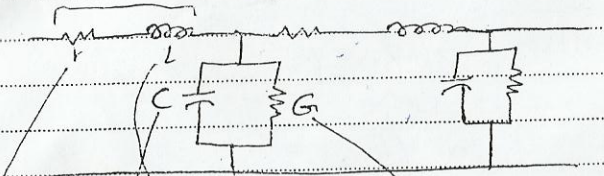
Subject: ....

Transmission line

- Overhead T.L
- Underground Cable

T.L Parameters :-

$Z \equiv$ Series impedance



Resistance

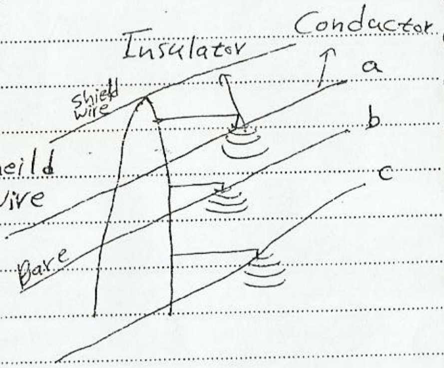
Inductance

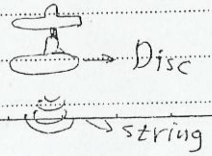
Conductance

Capacitance

Components of T.L :-

- Conductor
  - Copper
    - higher Conductivity
  - Aluminium
    - Low Cost
    - Lighter Wieght
    - It's Supply not Limited
- Insulator
- Supporting Structure
- Sheild Wire





Subject: .... / [2] /

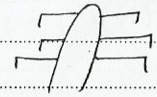
Conductor

- Solid
- Strands — سهل التناول
  - Easier to handle — سهل التصنيع
  - Easier to manufacture — أكثر مرونة
  - More flexible

Insulator

- Glass — زجاج
- Porcelgien (Porcelain)
- Rubber — مطاط

« شكل البرج » Supporting Structure →



Shield Wire — Lightning — الصاعقة

- Steel
- Aluminium

لحماية المكونات من الصاعقة
ويستخدم أيضاً في الاتصالات

Phase — Single Conductor
— Bundle حزمة

types of Aluminium

aluminum Conductor Steel Supported (ACSS) → Use for higer temperature $>150°C$ — مقوى

ACSR ≡ Alum. Condutore Steel Reinforced (most common)

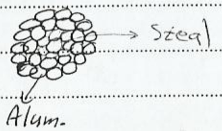
AAC ≡ All Alum. Cond. (« All Aluminum-Alloy Conductor ») AAAC

ACAR ≡ Alum. Cond. Alloy Reinforced — سبيكة

Aluminum-clad Steel Conductor (Alumoweld).

Ex

ACSR (24/7) — 24 → Alum., 7 → Steal



* T.L is based (design) on optimization (اختيار) of electrical, mechanical, enviromental (بيئية) and economic (اقتصادية) factors.

eletrical factors:

1. Voltage level — كل ما تزيد الجهد تنقل power أكثر
2. Cond. Capacity — ويستخدم في المسافات الطويلة
3. Strands
4. Bandle

Conductivity $\leftarrow \sigma = \frac{1}{\rho} \rightarrow$ resistivity

Symbol	SI Units	English Units
ρ	$\Omega \cdot m$	Ω Cmil/ft
L	m	ft
A	m^2	Cmil
$R_{dc} = \frac{\rho L}{A}$	Ω	Ω

1 inch = 1000 mil

القطر

d ≡ diameter

A (Cmil) = d^2

Circular mils

frequency ~~(Skin effect)~~ ظاهرة التشبع

(Skin effect)

$R_{ac} > R_{dc}$

Current density at the conductor Surface > أكبر من

Current density at the Center

$f \uparrow \Leftrightarrow$ Skin effect $\uparrow$

$$R_{ac} = \left(\begin{matrix}\text{factor} \\ \text{Sink effect}\end{matrix}\right) \cdot \left(R_{dc}\right)$$

mil ✕ mile mi

1mile = 63.36 ✱ 10^6 mil

1mile = 63360 inch

1mile = 5280 ft

1mile = 1760 yards

1mile = 1609 meter

1 yards = 3 ft

1 ft = 12 inch

1 inch = 2.54 cm

$A = d^2$ cmil $= \frac{\pi}{4} d^2$ Sq mil

1000D = 1d

Subject: ....

1 mil = 2.54 ✱ 10^{-8} Km

Resistance 8=

$$R_{dc} = \frac{\rho L}{A}$$

ρ → Resistivity; L → length; R_{dc} → resistance; A → Crossection Area مساحة المقطع

ρ_T ≡ Conductor resistivity at temperture (T)

L ≡ Conductor length

A ≡ Conductor Cross-Sectional Area

$$R_{ac} = \frac{P_{loss}}{|I|^2} \quad [\Omega]$$

$R_{ac} > R_{dc}$

Factors:

1. Material
2. length
3. ~~Tempture~~ Tempreture
4. CSA (Cross Section Area)
5. Spiralling (عدد اللفات) (1 → 2) % of length $\boxed{(1.01) L}$ 2%

$$R_2 = R_1 \frac{(T_2 + T_0)}{(T_1 + T)}$$

Temp Coefficient Bundle

$$\rho_{T_2} = \rho_{T_1} \left(\frac{T_2 + T}{T_1 + T}\right) \quad T \to [°C]$$

1mile = 63.36 ✱ 10^6 mil = 63360 inch = 5280 Ft = 1609 m

Ex 8

A 4/0 Copper Conductor With 12 Strands. Strand diameter is 0.1328 in. for this conductor.

a) Verify The total copper C.S.A of 211,600 cmil

b) // The dc resistance at 50°C of Ω/mi

Assume a 2% increase in resistance due to Spiralling ; $\rho_{20°C} = 10.66\ \Omega$ cmil/ft $T = 241.5°C$

c) From Table A3 determine The percent increa[se] in resistance at 60 Hz Versus dC

Solutoins

a)

dia 0.1328 in

$d = 0.1328 * 1000 = 132.8$ mil

C.S.A of 1 Strand $= d^2 = (132.8)^2 = 1763[5.84]$ cmil

C.S.A of the conductor $= 12 * 17635.84$

$= 211630.08$ cmil

$\simeq 211600$ cmil

b) $R_2 = R_1 \left(\frac{(T_2+T)}{(T_1+T)}\right)$

$\rho_2 = \rho_1 \left(\frac{(T_2+T)}{(T_1+T)}\right)$

$\rho_{50} = 10.66 \left(\frac{(50+241.5)}{(20+241.5)}\right)$

$\rho_{50} = 11.8829\ \Omega$.cmil/ft

$R_{50} = \rho_{50} \frac{L}{A} = \frac{11.88 * 5280 * 1.02}{211600} = 0.3024\ \Omega$/mi

c)

@ 60 Hz 25°C $\frac{R_{ac}}{R_{dc}} = \frac{0.278}{0.276} = 1.007$ $\boxed{0.7\%}$

@ 60 Hz 50°C $\frac{R_{ac}}{R_{dc}} = \frac{0.303}{0.302} = 1.003$ $\boxed{0.3\%}$

$100 + \frac{10 \times 100}{100}$

$R = \frac{11.88}{211600} = 5.614 \times 10^{-5}\ \frac{\Omega}{Ft}$

$= 5.614 \times 10^{-5} \times 5280$

$= 0.296\ \Omega$/mil

وعند إيجاد تأثير spiralling تصبح ((2%))

$0.296 + 0.296 \times \frac{2}{100} = 0.302$

H ≡ Magnetic field intensity

B ≡ Magnetic flux density   /   /

$$L = L_{int} + L_{ext}$$

internal   external

(Constant Value) ← $L_{int} = \frac{1}{2} \times 10^{-7}$ H/m

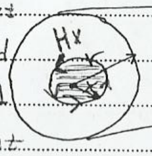
$$L_{ext} = 2 \times 10^{-7} \ln\left(\frac{D_2}{D_1}\right)$$

assume that the Conductor:

1) is sufficiently long that end effects are neglected

2) is nonmagnetic $\mu_r = 1$

3) has a uniform current density (skin effect is neglected)



$$\oint H_x \, dl = I_x$$

$$H_x L = N I_x \quad ; \quad N = 1$$

$$H_x (2\pi x) = I_x$$

① ← $\boxed{H_x = \frac{I_x}{2\pi x}}$ [A/m]

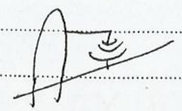
total current

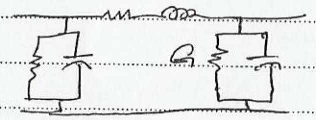
$$\frac{I}{\pi r^2} = \frac{I_x}{\pi x^2}$$ When Uniform

② ← $\boxed{I_x = \frac{x^2}{r^2} I}$ When uniform current distribution within the conductor

① & ② ← $\boxed{H_x = \frac{x^2 I}{2\pi x r^2} = \frac{x}{2\pi r^2} I}$

Conductance:





For OHTL There are power loss due to

i) leakage current at The insulators

ii) Corona: Occurs When high Value of electric field Strength ~~at~~ a conductor Surface causes the air to become electrically ionized and to conduct. ⇒ (Corona losses)

The real power loss due to corona, called corona loss

Inductance: ((Solid Cylindrical Conductor))

flux linkages

$$L = N \frac{d\phi}{dI} = \frac{N\phi}{I} = \frac{\lambda}{I}$$

$\boxed{\text{Lenz's law}}$ → for review → $L = N \frac{d\phi}{di_L}$ [H]

N = 1 باعتبار

$e_L = L \frac{di_L}{dt}$ [V]

$$L = \frac{\lambda}{I}$$

Inductance

$\mu \equiv$ Permeability

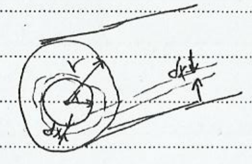
Subject: التفاضلية

$\mu_0 \mu_r \rightarrow \mu_r = 1$ nonmagnatic

$$B_x = \mu H_x$$

$$\boxed{B_x = \mu_0 H_x = \frac{\mu_0 I X}{2\pi r^2}} \quad [Wb/m^2] \; [Tesla]$$

$$\phi = BA \quad ; A = dx \cdot 1$$



Differential ϕ for a small region of dx for 1m long

$$\boxed{d\phi = B_x \, dx} \quad [Wb/m]$$

$$\boxed{d\phi = \frac{\mu_0 I X \, dx}{2\pi r^2}}$$

$$d\lambda_{int} = \frac{\pi x^2}{\pi r^2} \, d\phi$$

$$d\lambda = \frac{x^2}{r^2} \frac{\mu_0 I X}{2\pi r^2} \, dx$$

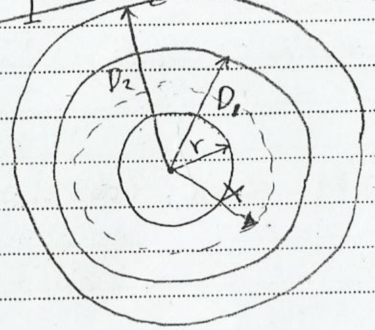
$$d\lambda = \frac{x^3 \mu_0 I}{2\pi r^4} \, dx$$

$$\lambda_{int} = \int_0^r \frac{x^3 \mu_0 I}{2\pi r^4} \, dx$$

λ interval

$$\lambda_{int} = \frac{\mu_0 I x^4}{8\pi r^4} \Bigg|_0^r = \frac{1}{2} * 10^{-7} I \quad [Wb\text{-}t/m]$$

$$\boxed{L_{int} = \frac{\lambda_{int}}{I} = \frac{1}{2} \times 10^{-7} \; H/m}$$



$$B_x = \frac{\mu_0 I_x}{2\pi x} = \frac{\mu_0 I}{2\pi X} \quad ; I = I_x$$

$$\phi_x = B_x A$$

$$d\lambda = d\phi$$

$$d\lambda = \frac{\mu_0 I}{2\pi X} \, dx$$

$$\lambda_{ext} = \int_{D_1}^{D_2} \frac{\mu_0 I}{2\pi X} \, dx$$

$$\lambda_{ext} = \frac{\mu_0 I}{2\pi} \ln\left(\frac{D_2}{D_1}\right) = 2I * 10^{-7} \ln\left(\frac{D_2}{D_1}\right)$$

$$\boxed{L_{ext} = 2 * 10^{-7} \ln\left(\frac{D_2}{D_1}\right)}$$

Subject:......................

$$L_{total} = L_{int} + L_{ext}$$

Inductance of Single phase two wire line :-

r_1 r_2

$\overset{d}{\longleftrightarrow}$

1^{st} Conductor

$$L_{ext} = 2\times10^{-7}\ Ln\left(\frac{D}{r_1}\right)$$

$$L_1 = \frac{1}{2}\times10^{-7} + 2\times10^{-7}\ Ln\left(\frac{D}{r_1}\right)$$

$$L_1 = 2\times10^{-7}\left[\frac{1}{4} + Ln\left(\frac{D}{r_1}\right)\right]$$

$$L_1 = 2\times10^{-7}\left[Ln\,e^{1/4} + Ln\left(\frac{D}{r_1}\right)\right] \qquad [H/m]$$

$$L_1 = 2\times10^{-7}\left[Ln\left(\frac{D e^{1/4}}{r_1}\right)\right]$$

$$L_1 = 2\times10^{-7}\left[Ln\left(\frac{D}{e^{-1/4} r_1}\right)\right]$$

conductor 1 $\quad L_1 = 2\times10^{-7}\,Ln\left(\frac{D}{r_1'}\right) \quad ; \quad r_1' = e^{-1/4} r_1 = 0.7788 r_1$

$$r_1' \equiv GMR \equiv D_s$$

Geometric mean radius

2nd Conductor

$$L_2 = 2\times10^{-7}\ Ln\left(\frac{D}{r_2'}\right) \quad ; \quad r_2' = e^{-\frac{1}{4}} r_2$$

conductor$_2$

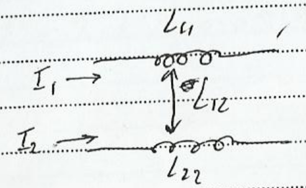
Total for Single phase

Single phase $\quad L_t = L_1 + L_2 \qquad [H/m]$

$$L = 2\times10^{-7}\ Ln\left(\frac{D}{r'}\right) = 2\times10^{-7}\ Ln\left(\frac{1}{r'}\right) + 2\times10^{-7}\ Ln(D)$$

Flux linkage in terms of Self and mutual inductances:

تبادلية



$$\lambda_1 = L_{11} I_1 + L_{12} I_2$$

Mutual inductance

Self inductance

$$\lambda_2 = L_{22} I_2 + L_{12} I_1$$

$$I_2 = -I_1$$

$$\lambda_1 = (L_{11} - L_{12})\, I_1$$

$$\lambda_2 = (L_{22} - L_{12})\, I_2$$

A Single phase T.L 35Km long Consists of two Solid round Conductors each having diameter of 0.9 cm the Conductor Spacing is 2.5m Calculate The inductance per Conductor and the total conductane of the Single phase line

Solution

$r' = 0.45 * 0.7788 * 10^{-2} = 3.5046 * 10^{-3}$ m

$L = 2*10^{-7} \ln\left(\frac{2.5}{3.5046*10^{-3}}\right) = 1.3139 * 10^{-6}$ H/m

$L = 10^{-6} * 1.3139 * 35000 = 0.0459$ H $= 45.9$ mH

$L_{total} = 2L = 0.0919$ H $= 91.9$ mH

For single phase $L_1 = 2*10^{-7} \text{Lin}\left[\frac{D}{r'}\right]$

Subject:...................... / / 8

$L_{11} = 2\times10^{-7} \ln\left(\frac{1}{r_1}\right)$

$L_{22} = 2\times10^{-7} \ln\left(\frac{1}{r_2}\right)$

$L_{21} = L_{12} = -2\times10^{-7} \ln(D)$

General $\boxed{\lambda_i = L_{ii} I_i + \sum_{J=1}^{n} L_{iJ} I_J \quad ; i \neq J \quad [Wb/m]}$

$\lambda_a = L_{aa} I_a + L_{ab} I_b + L_{ac} I_c$

$\lambda_b = L_{bb} I_b + L_{ba} I_a + I_{bc} I_c$

Similary:

$L = L_{int} + L_{ext} = 2\times10^{-7} \ln\left(\frac{D}{r'}\right) = 2\times10^{-7} \ln\left(\frac{1}{r'}\right) + 2\times10^{-7} \ln$

$L_{int} = \frac{1}{2}\times10^{-7}$

$L_{ext} = 2\times10^{-7} \ln\left(\frac{D}{r}\right)$

Subject:

$$\lambda_i = L_{ii} I_i + \sum_{J=1}^{n} L_{iJ} I_J \qquad i \neq J$$

$$\lambda_i = 2\times10^{-7}\left[I_i \ln\frac{1}{r_i} + \sum_{J=1}^{n} I_J \ln\frac{1}{D_{iJ}}\right] \qquad i \neq J$$

$$\lambda_1 = \lambda_{11} + \lambda_{12}$$

$$= L_{11} I_1 + L_{12} I_2 + L_{13} I_3$$

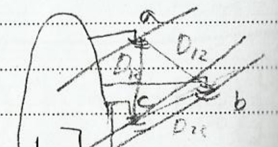
$$= \left(2\times10^{-7} \ln\frac{1}{r_1}\right) I_1 + \left(2\times10^{-7} \ln\left(\frac{1}{D_{12}}\right)\right) I_2$$

$$+ \left(2\times10^{-7} \ln\left(\frac{1}{D_{13}}\right)\right) I_3$$

Inductance of Three phase T.L :

1) Symmetrical Spacing المسافات متساوية
("Balancing System") $I_a + I_b + I_c = 0$

$$D_{12} = D_{13} = D_{23} = D$$



$$\lambda_a = 2\times10^{-7}\left[I_a \ln\frac{1}{r_a} + I_b \ln\frac{1}{D_{ab}} + I_c \ln\frac{1}{D_{ac}}\right]$$

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\left(\frac{1}{r_a}\right) + I_b \ln\left(\frac{1}{D}\right) + I_c \ln\left(\frac{1}{D}\right)\right]$$

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\left(\frac{1}{r_a}\right) - I_a \ln\left(\frac{1}{D}\right)\right]$$

$$\boxed{\lambda_a = 2\times10^{-7} I_a \left[\ln\left(\frac{D}{r_a}\right)\right]}$$

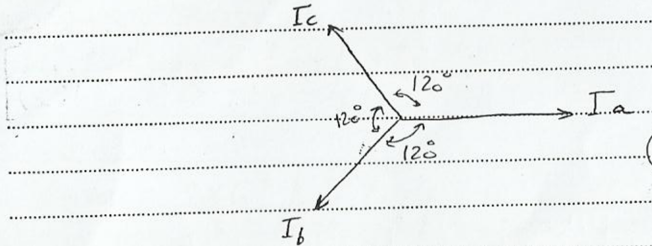
$$L_a = \frac{\lambda_a}{I_a} = 2\times10^{-7} \ln\left(\frac{D}{r}\right)$$

$$L_a = L_b = L_c$$

2) ASymmetrical Spacing :

$$D_{12} \neq D_{13} \neq D_{23} \neq D$$

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\frac{1}{r_a} + I_b \ln\left(\frac{1}{D_{12}}\right) + I_c \ln\left(\frac{1}{D_{13}}\right)\right]$$



$a = 1 \angle 120$
$a^2 = 1 \angle 240$
$a + a^2 + 1 = 0$

$$I_b = a^2 I_a$$

$$I_b = I_a \angle 240$$

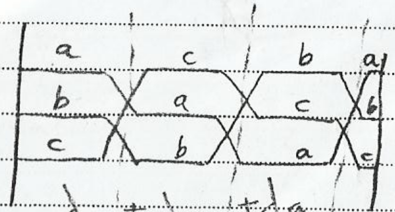
$$I_c = a I_a = I_a \angle 120$$

$$\lambda_a = 2\times10^{-7}\left[I_a \ln\left(\frac{1}{r}\right) + a^2 I_a \ln\left(\frac{1}{D_{ab}}\right) + a I_a \ln\left(\frac{1}{D_{ac}}\right)\right]$$

$$\lambda_a = 2\times10^{-7} I_a\left[\ln\left(\frac{1}{r}\right) + a^2 \ln\left(\frac{1}{D_{ab}}\right) + a \ln\left(\frac{1}{D_{ac}}\right)\right]$$

pose line $\frac{\circ}{\circ}\square$

$$L_a \times L_b \times L_c$$
$$> 100\,Km$$



$$\lambda_{a_1} + \lambda_a + \lambda_a = \lambda_a$$
$$\lambda_b + \lambda_b + \lambda_b = \lambda_b$$
$$\lambda_c + \lambda_c + \lambda_c = \lambda_c$$

متساويات

$$L_{avg} = \frac{L_a + L_b + L_c}{3}$$

$$L_{avg} = \frac{2\times10^{-7}}{3}\Big[3\,Ln\left(\frac{1}{r}\right) + Ln\left(\frac{1}{D_{12}}\right)(a+a^2) + Ln\left(\frac{1}{D_{13}}\right)(a+a^2)$$
$$+ Ln\left(\frac{1}{D_{23}}\right)(a+a^2)\Big]$$

$$\boxed{L_{avg} = 2\times10^{-7}\,Ln\left(\frac{GMD}{r}\right) \quad ; GMD \to \sqrt[3]{D_{12}D_{13}D_{23}}}$$

Subject: $I_c = a^2 I_b$ $\quad I_a = a I_b \quad I_a = \frac{I_b}{a^2}$, $I_c = \frac{I_b}{a}$ / / 10

$$\boxed{L_a = \frac{\lambda_a}{I_a} = 2\times10^{-7}\left[Ln\left(\frac{1}{r}\right) + a^2\,Ln\left(\frac{1}{D_{ab}}\right) + a\,Ln\left(\frac{1}{D_{ac}}\right)\right]}$$

$$\lambda_a \times \lambda_b \times \lambda_c$$
$$L_a \times L_b \times L_c$$

$$\lambda_b = 2\times10^{-7}\left[I_b\,Ln\left(\frac{1}{r}\right) + I_a\,Ln\left(\frac{1}{D_{ba}}\right) + I_c\,Ln\left(\frac{1}{D_{bc}}\right)\right]$$

$$\boxed{L_b = \frac{\lambda_b}{I_b} = 2\times10^{-7}\left[Ln\left(\frac{1}{r}\right) + a\,Ln\left(\frac{1}{D_{ba}}\right) + a^2\,Ln\left(\frac{1}{D_{bc}}\right)\right]}$$

$$\lambda_c =$$

$$\boxed{L_c = 2\times10^{-7}\left[Ln\left(\frac{1}{r}\right) + a^2\,Ln\left(\frac{1}{D_{cb}}\right) + a\,Ln\left(\frac{1}{D_b}\right)\right]}$$

$I_b = a^2 I_a$ $\qquad a^2 + a + 1 = 0$

$I_b = I_a \angle 240$

i = a

$$\lambda_{a(I)} = 2\times10^{-7}\left[I_a \ln\frac{1}{r'} + I_b \ln\frac{1}{D_{12}} + I_c \ln\frac{1}{D_{13}}\right]$$

2 $i = a$

$$\lambda_{a(II)} = 2\times10^{-7}\left[I_a \ln\frac{1}{r'} + I_c \ln\frac{1}{D_{13}} + I_b \ln\frac{1}{D_{23}}\right]$$

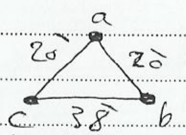
3 $i = 2$

$$\lambda_{a(III)} = 2\times10^{-7}\left[I_a \ln\frac{1}{r'} + I_b \ln\frac{1}{D_{13}} + I_c \ln\frac{1}{D_{23}}\right]$$

$$\lambda_{a(avg)} = \frac{\lambda_{a(I)} + \lambda_{a(II)} + \lambda_{a(III)}}{3}$$

$$\boxed{\begin{gathered}\lambda_a = 2\times10^{-7} I_a \ln\frac{GMD}{r'} \\ GMD = \sqrt[3]{D_{12} D_{12} D_{23}} \\ L_a = \frac{\lambda_a}{I_a} = 2\times10^{-7} \ln\frac{GMD}{GMr}\end{gathered}}$$

Ex:
A Single circuit, Three phase transposed line operated at 60Hz is arranged as Shown.
The conductors are ACSR Drake, Find The inductive reactance per mile per phase



Subject:....................... / / 11

Similary :

$$L = 2\times10^{-7} \ln\left(\frac{GMD}{GMR}\right)$$

GMD → D → Single Phase

GMD → D → three Phase Symmetrical

GMD → $\sqrt[3]{D_{12} D_{13} D_{23}}$ → three Phase

GMR = r' → for all

خليط/مجموعة

Inductance of Composite Conductor lines :-

Conductor X — Conductor y

$\uparrow I$ — $\downarrow I$

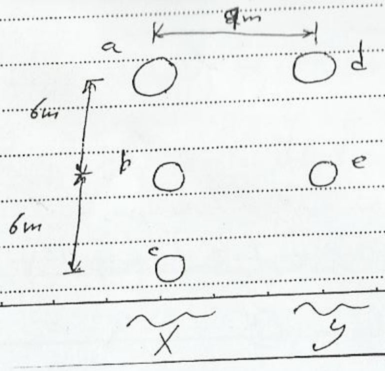
L_x — L_y

$$\boxed{L_x = 2\times10^{-7} \ln\left(\frac{D_m}{D_{sx}}\right)}$$ → mutual Geomtric Mean Distance

$$\boxed{L_y = 2\times10^{-7} \ln\left(\frac{D_m}{D_{sy}}\right)}$$

Example :-

One Circuit of a Single phase T.L is composed of Three Solid 0.25cm radius Wires, The return circuit is composed of two 0.5cm radius wires. Find The inductance due to each current in each Side of the Line & The inductance of The complete line in henery per meter & in mH/mi



Note

الملفات بعضها

bandle مش

Subject:..........

' → feet

'' → inch

Solution

$$X_L = WL$$

$$L = 2\times10^{-7} \ln\left(\frac{GMD}{GMR}\right)$$

$$GMD = \sqrt[3]{(20)(20)(38)} = 24.8 \text{ ft}$$

$$GMR = r' = D_s = 0.0373 \text{ ft}$$

$$L = 2\times10^{-7} \ln\left(\frac{24.8}{0.0373}\right) = 13 * 10^{-7} \text{ H/m}$$

$$X_L = 2\pi(60) * 13 * 10^{-7} = 4.9 * 10^{-4} \ \Omega/m$$

$$\boxed{1\text{mile} = 1609 \text{ m}}$$

$$X_L = 4.9 * 10^{-4} * 1609 = 0.788 \ \Omega/mi$$

Solution

$L_x = 2\times10^{-7} Ln\left(\frac{D_m}{D_{sx}}\right)$

$D_m = \sqrt[3\times2]{D_{ad} D_{ae} D_{bd} D_{be} D_{cd} D_{ce}}$

$= 10.743 m$

$D_{ce} \rightarrow$ 9m, 6m, D_{ce} $\quad D_{ce} = \sqrt{6^2+9^2} =$

$D_{sx} = \sqrt[3\times3]{D_{aa} * D_{ab} * D_{ac} * D_{bb} * D_{ba} * D_{bc} * D_{cc} * D_{ca} * D_{cb}}$

$D_s = GMR = r'$

$D_s = 0.25 * 0.7788 * 10^{-2} = 1.947 * 10^{-3} m$

$D_{sx} = \sqrt[9]{\quad}$

$D_{sx} = 0.481 m$

$L_x = 2\times10^{-7} Ln\left(\frac{10.743}{0.481}\right) = 6.212 * 10^{-7}$ H/m

$D_{sy} = \sqrt[2\times2]{D_{dd} * D_{de} * D_{ee} * D_{ed}} = 0.153 m$

$L_y = 2\times10^{-7} Ln\left(\frac{10.743}{0.153}\right) = 8.503\times10^{-7}$ H/m

$L_{tot} = L_x + L_y = 14.715 * 10^{-7}$ H/m

$L_{tot} = \frac{14.715 * 10^{-7} * 1609}{1000} = 2.37$ mH/mi

GMR of Bundled conductors :-

1. Improve (يحسّن) the line performance (أداء)
2. Increases power capability (سعة) of the line
3. Reduces (ينقص) Corona losses

$D_s^b = \sqrt[4]{D_s * d * D_s * d} = \sqrt{D_s d}$

$= \sqrt[9]{D_s^3 d^6} = \sqrt[3]{D_s d^2}$

* لو أعطى r نطلع D_s بالضرب في 0.7788
* كان فيه جدول فإنه D_s الي في الجدول هي نفسها r'

$D_s = r'$

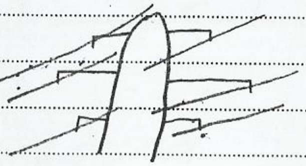
$r' = r * 0.7788$

~~~nce of Three phase double circuit line:

a O   O c'

b O   O b'

c O   O a'



$L_a = L_b = L_c$

$GMD = \sqrt[3]{D_{AB} * D_{BC} * D_{AC}}$

$D_{AB} = \sqrt[4]{D_{ab} * D_{ab'} * D_{a'b} * D_{a'b'}}$

$D_{BC} = \sqrt[4]{D_{bc} * D_{bc'} * D_{b'c} * D_{b'c'}}$

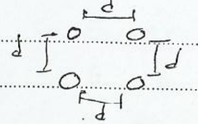
$D_{AC} = \sqrt[4]{D_{ac} * D_{ac'} * D_{a'c} * D_{a'c'}}$

$D_{SA} = \sqrt[4]{D_{aa} * D_{aa'} * D_{a'a} * D_{a'a'}} = \sqrt{D_s D_{aa'}}$

$D_{SB} = \sqrt[4]{D_{bb} D_{bb'} D_{b'b} D_{b'b'}} = \sqrt{D_s D_{bb'}}$

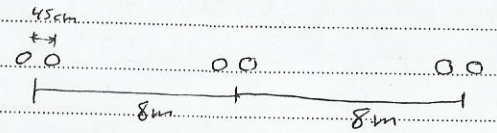
$D_{SC} = \sqrt[4]{D_{cc} D_{cc'} D_{c'c} D_{c'c'}} = \sqrt{D_s D_{cc'}}$

$GMR = \sqrt[3]{D_{SA} * D_{SB} * D_{SC}}$



$D_s^d = \sqrt[16]{(D_s \sqrt{2}\, d^3)^4} = 1.09\sqrt[4]{D_s d^3}$

Ex:



ACSR Pheasant

$X_L = ?\ [\Omega / Km]$

$GMD = \sqrt[3]{8 \times 16 \times 8} = 10.0794\ m$

~~GMR~~ =

from Table D_s = 0.0466 ft = 0.0142 m (for phase)

for bundle $\rightarrow D_s^b = \sqrt{D_s d} = \sqrt{(0.0142)(0.45)} = 0.0799\ m$

$L = 2 \times 10^{-7} \ln\left(\frac{GMD}{GMR}\right) = 9.67 \times 10^{-7}\ H/m$

$L = 9.67 \times 10^{-4}\ H/Km$

$X_L = 2\pi(60)(L) = 0.3647\ \Omega/Km$
~~~

adjacent ⇒ مجاور

GMD ≡ Geometric mean distance

Capacitance :
The amount of capacitance between Conductors (مجموعة كلية)
is a function of :

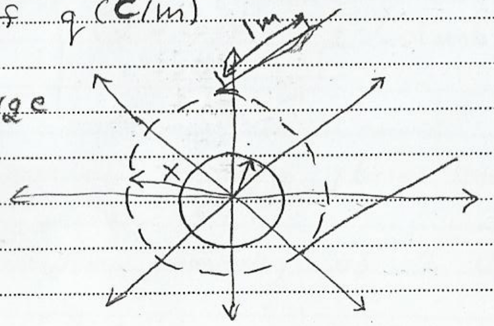
~~Consider a long round Cond. With~~

1. Conductor Size.
2. Spacing between Conductors
3. height above ground

* Consider a long round Conductor with radius r carrying a charge of q (C/m)

flux charge

$\psi = Q$



* The charge on conductor gives rise to an electric field with radial flux lines

* The total electric flux is numerically equals the Value of charge on conductor.

GMR ≡ Geometric mean radius

Subject: bundle 15

a oo oo a'
b oo oo b'
c oo oo a'

الفرق في D_s
تحسب D_s^b وتعوض
بيها

$$D_s^b = \sqrt{D_s \times d}$$

$$D_{SA} = \sqrt{D_s^b D_{aa'}}$$

$$D_{SB} = \sqrt{D_s^b D_{bb'}}$$

واصل المسألة 25
من
Glover

Gauss's Law :

$$D = \frac{q}{A} \qquad C = \frac{Q}{V}$$

electric field density

$$D = \frac{q}{2\pi X (L)} = \frac{q}{2\pi X * 1} = \frac{q}{2\pi X}$$

$$E = \frac{D}{\epsilon}$$

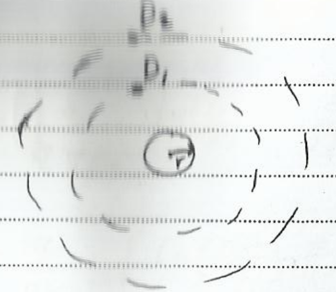
electric field intensity

ϵ → Permettivity $\epsilon_0 \epsilon_r$

$$E = \frac{q}{2\pi X \epsilon_0}$$

The potential difference between Cylinders from position D_1 to D_2 is defind at the work done in moving a unit charge of 1 Coulomb from D_2 to D_1 Through The electric field produced by the charge ~~[illegible]~~ on conductor

$$V_{12} = \int_{D_1}^{D_2} E \, dx$$



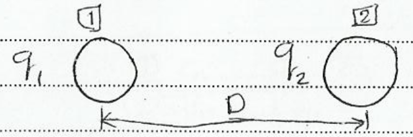
$$\boxed{V_{12} = \int_{D_1}^{D_2} \frac{q}{2\pi \epsilon_0 X} dx = \frac{q}{2\pi \epsilon_0} Ln\left(\frac{D_2}{D_1}\right) \quad [V/m]}$$

$$\boxed{\underset{C/m}{q} * \underset{m}{L} \;\; [\text{Colomb}]} \quad Q = q * L$$

Capacitance of a Single phase lines :

Single phase line consisting of 2 Conductors With 1m long

$\boxed{q = q_1 = -q_2}$



* Assuming cond. ① is alone

$$V_{12}(q_1) = \frac{q_1}{2\pi \epsilon_0} Ln\left(\frac{D}{r}\right)$$

* Assuming Cond. ② is alone

$$V_{21(q_2)} = \frac{q_2}{2\pi\epsilon_0} \ln\left(\frac{D}{r}\right)$$

$$\boxed{\therefore \quad V_{12(q_1)} = -V_{21(q_2)}}$$

q_2 [illegible] $\longrightarrow$ $\boxed{V_{12(q_1)} = \frac{q_2}{2\pi\epsilon_0} \ln\left(\frac{r}{D}\right)}$

$$\boxed{V_{12} = V_{12(q_1)} + V_{12(q_2)}}$$

$$\cancel{V_{12} = \frac{q}{2\pi\epsilon_0}\left[\ln\left(\frac{D}{r}\right) + \ln\left(\frac{r}{D}\right)\right]}$$

$$\cancel{V_{12} = \frac{q}{2\pi\epsilon_0}}$$

$$V_{12} = \frac{q_1}{2\pi\epsilon_0} \ln\left(\frac{D}{r}\right) + \frac{q_2}{2\pi\epsilon_0} \ln\left(\frac{r}{D}\right)$$

$$q_1 = -q_2 = q$$

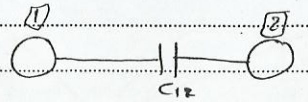
.... / /

$$V_{12} = \frac{q}{2\pi\epsilon_0} \ln\left(\frac{D}{r}\right) - \frac{q}{2\pi\epsilon_0} \ln\left(\frac{r}{D}\right)$$

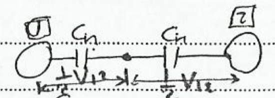
$$V_{12} = \frac{q}{2\pi\epsilon_0}\left[\ln\left(\frac{D}{r}\right)^2\right] = \frac{q}{\cancel{2}\pi\epsilon} * \cancel{2}\ln\left(\frac{D}{r}\right)$$

for Single phace $\boxed{V_{12} = \frac{q}{\pi\epsilon_0} \ln\left(\frac{D}{r}\right)}$ [V/m]

$$\boxed{C_{12} = \frac{q}{V_{12}} = \frac{\pi\epsilon_0}{\ln\left(\frac{D}{r}\right)} \quad [f/m]}$$

* 

$C_{12} \rightarrow$ Line to Line Capacitance

* 

$C_n \rightarrow$ Capacitane to neutral

$$\boxed{C_n = \frac{2\pi\epsilon_0}{\ln\left(\frac{D}{r}\right)} \quad f/m}$$

$$C_{12} = \frac{C_n^2}{2C_n} = \frac{C_n}{2}$$

$$\boxed{C_n = 2\, C_{12} \quad f/m}$$

$$\boxed{C_n = \frac{0.0556}{\ln\left(\frac{D}{r}\right)} \quad \mu F/Km}$$

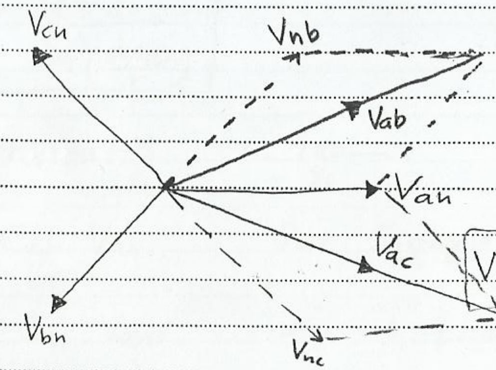
$$\ldots\frac{1}{2\pi\epsilon_0}\left[q_a \underbrace{\ln\left(\frac{D}{D}\right)}_{0} + q_b \ln\left(\frac{D}{r}\right) + q_c \ln\left(\frac{r}{D}\right)\right].$$

$$V_{ac} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D}{r}\right) + q_b \underbrace{\ln\left(\frac{D}{D}\right)}_{0} + q_c \ln\left(\frac{r}{D}\right)\right]$$

$$V_{ab} + V_{bc} = \frac{1}{2\pi\epsilon_0}\left[2q_a \ln\left(\frac{D}{r}\right) - q_a \ln\left(\frac{r}{D}\right)\right]$$

$$'' = '' \left[2q_a \ln\left(\frac{D}{r}\right) + q_a \ln\left(\frac{D}{r}\right)\right]$$

$$\boxed{V_{ab} + V_{bc} = \frac{3}{2\pi\epsilon_0} q_a \ln\left(\frac{D}{r}\right)}$$



$$\boxed{V_{LL} = \sqrt{3}\, V_{ph} \angle 30^\circ}$$

$$V_{ab} = V_{an} + V_{nb} = \sqrt{3}\, V_{an} \angle 30^\circ = \sqrt{3}\, V_{an}\left[\frac{\sqrt{3}}{2} + j\frac{1}{2}\right]$$

$$V_{ac} = V_{an} + V_{nc} = \sqrt{3}\, V_{an} \angle -30 = \sqrt{3}\, V_{an}\left[\frac{\sqrt{3}}{2} - j\frac{1}{2}\right]$$

$$V_{ab} + V_{ac} = 3V_{an}$$

Potenzial Difference in a multi-Conductor Configuration:

$$\boxed{V_{ij} = \frac{1}{2\pi\epsilon_0} \sum_{k=1}^{n} q_k \ln\left(\frac{D_{kj}}{D_{ki}}\right)}$$

for three phase

$$\boxed{V_{12} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\frac{D_{12}}{D_{11}} + q_b \ln\frac{D_{22}}{D_{21}} + q_c \ln\frac{D_{32}}{D_{31}}\right]}$$

Capacitance of 3-phase trasmission lines:

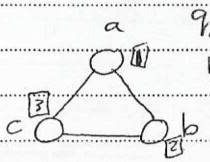
$I_a + I_b + I_c = 0$

$q_a + q_b + q_c = 0$

$r_a = r_b = r_c = r$

$D_{12} = D_{23} = D_{31} = D$

[1] Symmetrical Spacing



$$V_{ab}_{ij} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D_{12}}{\cancel{D_{11}}\, r}\right) \to D_{11}\right.$$

$$\left. + q_b \ln\left(\frac{\overset{=D_{22}}{\cancel{D}\, r}}{D_{12}}\right) + q_c \underbrace{\ln\left(\frac{D_{32}}{D_{31}}\right)}_{0}\right]$$

$\ln(1) = 0$

$$V_{ab} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D}{r}\right) + q_b \ln\left(\frac{r}{D}\right)\right]$$

$$V_{ab(avg)} = \frac{V_{ab(I)} + V_{ab(II)} + V_{ab(III)}}{3}$$

$$GMD = \sqrt[3]{D_{12} D_{13} D_{23}}$$

$$V_{ab(avg)} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{GMD}{r}\right) + q_b \ln\left(\frac{r}{GMD}\right)\right]$$

Similar

$$V_{ac} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{GMD}{r}\right) + q_c \ln\left(\frac{r}{GMD}\right)\right]$$

$$V_{ab} + V_{ac} = \frac{3q_a}{2\pi\epsilon_0} \ln\left(\frac{GMD}{r}\right)$$

$$\boxed{C_{an} = \frac{2\pi\epsilon_0}{\ln\left(\frac{GMD}{r}\right)}}$$

Charging Current : X_L X_C

$\frac{V}{X_C} = I_{ch} = JW\ C_{ab}\ V_{ab}$ for Single phase line

$I_{ch} = JW\ C_n\ V_{an}$ " 3-phase T.L

$\downarrow$

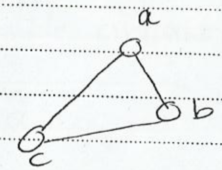
phase to neutral voltage

$$3V_{an} = \frac{3q_a}{2\pi\epsilon_0} \ln\left(\frac{D}{r}\right)$$

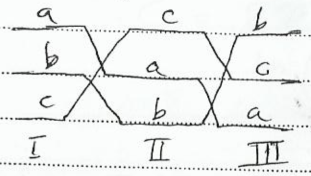
Capacitance to neutral $\boxed{C_{an} = \frac{q_a}{V_{an}} = \frac{2\pi\epsilon_0}{\ln\left(\frac{D}{r}\right)} \quad f/m}$

$$C_{an} = \frac{0.0556}{\ln\left(\frac{D}{r}\right)} \quad \mu f/Km$$

2 Asymmetrical Spacing :



transposition



$$V_{ab(I)} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D_{12}}{r}\right) + q_b \ln\left(\frac{r}{D_{12}}\right) + q_c \ln\left(\frac{D_{23}}{D_{13}}\right)\right] \quad C=3 \quad 12$$

$$V_{ab(II)} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D_{23}}{r}\right) + q_b \ln\left(\frac{r}{D_{32}}\right) + q_c \ln\left(\frac{D_{13}}{D_{12}}\right)\right] \quad C=1 \quad 23$$

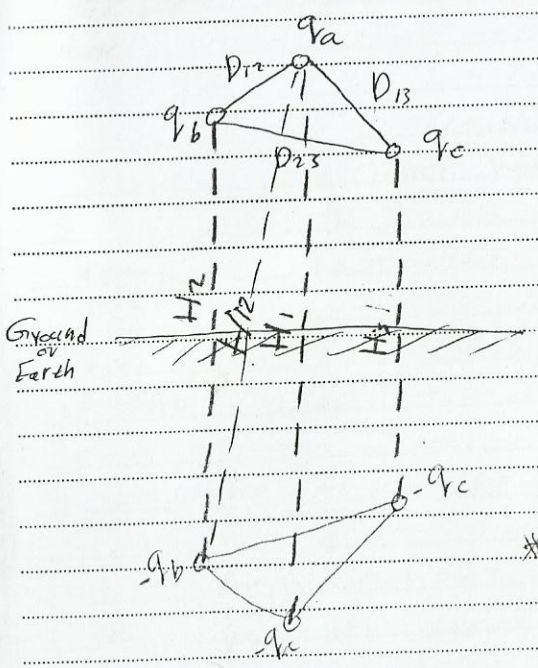
$$V_{ab(III)} = \frac{1}{2\pi\epsilon_0}\left[q_a \ln\left(\frac{D_{31}}{r}\right) + q_b \ln\left(\frac{r}{D_{13}}\right) + q_c \ln\left(\frac{D_{21}}{D_{23}}\right)\right] \quad C=2 \quad 31$$

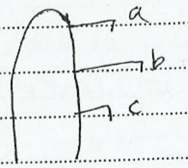
...ct of earth on the capacitance of 3ϕ

...l.s=

Assuming That The earth is perfect conductor in the from of the horizontal plane of infinte extent.

$$V_{ab} = \frac{1}{2\pi\epsilon_0}\left[q_a\left[Ln\left(\frac{D_{12}}{r}\right) - Ln\left(\frac{H_{12}}{H_1}\right)\right] + q_b\left[Ln\left(\frac{r}{D_{12}}\right) - Ln\left(\frac{H_2}{H_{12}}\right)\right] + q_c\left[Ln\left(\frac{D_{23}}{D_{13}}\right) - Ln\left(\frac{H_{23}}{H_{13}}\right)\right]\right]$$





$$\boxed{C_n = \frac{2\pi\epsilon_0}{Ln\left(\frac{GMD}{r}\right) - Ln\left(\frac{\sqrt[3]{H_{12}H_{13}H_{23}}}{\sqrt[3]{H_1H_2H_3}}\right)}}$$

* The effect of earth is to increase the Capacitane of the line.

Subject:

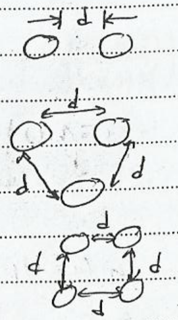
Effects of Bundling:

$$C_n = \frac{2\pi\epsilon_0}{Ln\left(\frac{GMD}{r^b}\right)}$$

$r^b = \sqrt{r*d}$

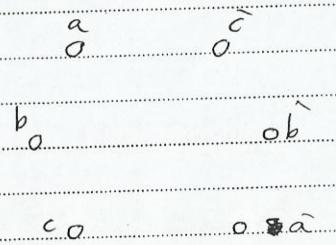
$r^b = \sqrt[3]{r*d^2}$

$r^b = 1.09\sqrt[4]{r*d^3}$



Capacitance of Three phase double circuit lines:

$$C_n = \frac{2\pi\epsilon_0}{Ln\left(\frac{GMD}{GMR_c}\right)}$$



$GMR_c = \sqrt[3]{Z_A * Z_B * Z_C}$

$Z_A = \sqrt{r * D_{aa'}}$

$Z_B = \sqrt{r * D_{bb'}}$

$Z_C = \sqrt{r * D_{cc'}}$

$GMD = \sqrt[3]{D_{AB} * D_{BC} * D_{AC}}$

Similar to inductance

ind the ~~Inductance~~ inductive reactance of a Single phase line opearting at 60 Hz. The Cond. is partridge and Spacing is 20 ft.

Solution

for Conductor $L = 2 * 10^{-7} \ln\left(\frac{GMD}{GMR}\right) = 2 * 10^{-7} \ln\left(\frac{20}{0.0217}\right)$

$L = 1.36 * 10^{-6}$ H/m

for Single phase $L = 2 * L_{\text{for conductor}}$

$L = 2.73 * 10^{-3}$ H/m

$X_L = 1.6553\,9\ \Omega/mi$

Other Way

from A.3 table $X_a = 0.465\ \Omega/mi$

from table A.4 $X_d = 0.3635\ \Omega/mi$ @ 20

for Conductor $X_L = X_a + X_d = 0.8285\ \Omega/mi$

for Single phase $X_L = 1.657\ \Omega/mi$

Subject:........................

21

The use of table in Inductane :-

$X_L = WL = 2\pi f L = 2\pi f * 10^{-7} \ln\left(\frac{GMD}{GMR}\right)$

$X_L = 4\pi f * 10^{-7} \ln\left(\frac{GMD}{GMR}\right)\ \Omega/m$

$* 1609$

$X_L = 2.022 * 10^{-3} f \ln\left(\frac{GMD}{GMR}\right)\ \Omega/mi$

$X_L = \underbrace{2.022 * 10^{-3} f \ln\left(\frac{1}{GMR}\right)}_{X_a} + \underbrace{2.022 * 10^{-3} f \ln(GMD)}_{X_d}$

$X_a \triangleq$ Inductive reattane at 1 ft Spacing

$X_d \triangleq$ " " Spacing factor

GMR$_c$

from table

dia = 0.68 inch

$GMR_c = \frac{0.68}{2}$ inch $= \frac{\square}{12} = 0.0283$ ft

$r = \sqrt{r_A r_B r_C}$

$r_A = \sqrt{GMR_c * D_{aa'}} = 0.8725$ ft

$r_B = \sqrt{GMR_c * D_{bb'}} = 0.7709$ ft

$r_C = \sqrt{GMR_c * D_{cc'}} = 0.8725$ ft

$r = \sqrt[3]{r_A\, r_B\, r_C} = 0.837$ ft

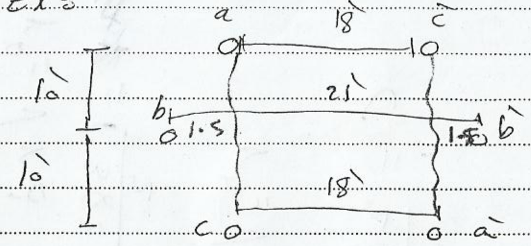
$C_n = \frac{2\pi\epsilon_0}{\ln\left(\frac{16.1}{0.837}\right)} = 18.79 * 10^{-12}$ F/m

$B_c = W C_n = 2\pi f\, C_n = 7.083 * 10^{-9}$ S/m

$\boxed{B_c = 11.39 * 10^{-6} \text{ S/mi}}$

Subject:................ / / 22

Exe



$D_{ab} = \sqrt{1.5^2 + 10^2} = 10.$ ft

$D_{ab'} = \sqrt{19.5^2 + 10^2} = 21.9$ ft

$D_{a'b} = 21.9$ ft

$D_{a'b'} = 10.1$ ft

ACSR Ostrich

Find the 60 Hz capacitance susceptance B to neutral per mile per phase

$C_n = \frac{2\pi\epsilon_0}{\ln\left(\frac{GMD}{r}\right)}$

$GMD = \sqrt[3]{D_{AB} D_{BC} D_{AC}}$

$D_{AB} = \sqrt[4]{D_{ab} * D_{ab'} * D_{a'b} * D_{a'b'}} = 14.88$ ft

$D_{BC} = \sqrt[4]{D_{bc} * D_{bc'} * D_{b'c} * D_{b'c'}} = 18.97$ ft

$D_{AC} = \qquad =$

GMD = 16.1 ft

E

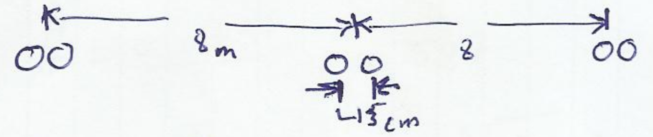
For the bandel cond. Line shown in Fig each is ACSR 1.270.000 cmil Pheasant Find

a → The inductance of the Line in mH/Km/ph and The inductive reactance

b → The series impedance in Ω/mi/ph

c → The Capacitance of the Line in μF/Km/ph and total capacitve reactance at 60 Hz if the Line is 120 Km

D → The charging current per Km if operating Voltage 220 KV



<u>slouzion</u> (a)

Bandel , ACSR,

اولا مش عاطى دايمتر او الـ r إزاى من جدول

<u>From the table</u>

$D_s = GMR_o = 0.0466\ Ft$

للبندل الواحد فقط للسنقل كوندكتر

$$L = 2*10^{-7} \, Ln \frac{GMR_x}{GMD}$$

بما أنها ثرى فيز

$$GMD = \sqrt[3]{8\ 8\ 16} = 10.08m$$

$$GMR_x = \sqrt{D_s d} = \quad = 0.025$$

$$= \sqrt{0.45\left(\frac{0.0466*12*2.54}{2.54}\right)} = 0.0799m$$

$$L = 2*10^{-7} Ln\left(\frac{10.08}{0.0799}\right) = 0.967*10^{-6}\ H/m$$

1

$x_L = \omega L = 2\pi * 60 * 0.967 * 10^{-6} = \boxed{\checkmark} \quad \Omega/m$

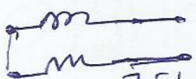
$= \boxed{\checkmark} * 1000 \ \Omega/Km \qquad 0.365 \ \Omega/Km$

b series impedane . $Z = R + jx_L$

$x_L = 0.365 \times 1.609 = 0.587 \ \Omega/mi$

بالذهاب الى جدول نطاق R

$R_{20^\circ C} = 0.0751 \ \Omega/mi$



$Z = \frac{0.0751}{2} + 0.587$

if Bandel (3) . ... $\sqrt[3]{D_s d^2}$ $\qquad \frac{R}{3}$

i Bandel (4) . $1.09 \sqrt[4]{D_s d^3}$ $\qquad \frac{R}{4}$

c

$C = \frac{2\pi \varepsilon_0}{Lin\left(\frac{GMR}{r^b}\right)}$ bandel

نطاق r من جدول

$r = \frac{diam}{2}$

$r^b = \sqrt{rd} =$

$r = \frac{1.382}{2}$ inch $= \frac{0.691 * 2.54}{100} = 0.0176m$

$r^b = \sqrt{0.0176 * 0.45} = 0.089$

$C = \frac{2\pi \ 8.85 * 10^{-12}}{Lin\left(\frac{10.08}{0.089}\right)} = 11.75 * 10^{-12} \ F/m$

$x_c = \frac{1}{\omega C} = \frac{1}{2\pi * 60 * 11.75 * 10^{-12}} = \boxed{\checkmark} \ \Omega/m$ $\quad 225.866 * 10^{6}$

$\frac{225.866 * 10^{6}}{120 * 10^{3}} = 1882$

$x_C = \frac{1}{\omega C_T} = 1883$

$C_T = 0.01175 \times 120 = 1.409 \mu F$

$\omega = 2\pi f c$

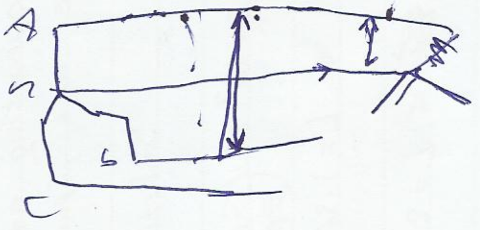
2

إذا جهد يعطى في المثال Line to Line

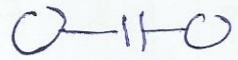
(D) $I_{ch} = j\omega C_n V_{an}$

$= j\,(2 * 60 * 11.76 * 10^{-12}) * \frac{220 * 10^3}{\sqrt{3}} = \square\, A/m$ $\boxed{0.563 \ A/Km}$

وماا Line to phase



$\frac{2\pi\varepsilon_0}{\ln(\,)}$



$\frac{\pi\varepsilon_0}{\ln(\,)}$

(E) total reactive Power of the Line

$Q_{3ph} = \sqrt{3}\, V_{LL} I = \sqrt{3}\ 220 * 10^3 * 0.563 =$

if onephase $Q_{1\phi} = V_{ph}\, I$